Warren Deutsch:
Design of a Satellite Controlling Instrument Panel (A)

In January 1958, Warren Deutsch, head of the Value Engineering Department at Philco-Ford in Palo Alto, California, was helping a co-worker, John Chavonec, find where to buy photosensors[1] for an instrument panel in a satellite controlling ground station. "John and I discussed the situation," said Mr. Deutsch, "but I couldn't formulate a clear mental picture of exactly what it was he needed. I felt I'd be more help if I could see the instrument panel, and also my curiosity was getting the best of me." Mr. Chavonec led Mr. Deutsch to a room which doubled as a customer showroom and a testing area for the Human Factors Department. There he pointed to a full scale mock-up of the instrument panel, explained its operation and told why he felt photosensors were needed. "Once John had explained the problem," said Mr. Deutsch, "I knew I'd have no trouble locating the photosensors he needed. I'd worked with photosensors on other projects and knew several vendors who could give us the low-down on the proper type of photosensor for this job. But I'd also become intrigued with the manner of operating the instrument panel. It struck me as being a real hassle for the operator; too many manipulations were involved meaning wasted time and effort. I felt I could design a better one."

[1] Photosensors are activated by the presence or absence of light. Equipment incorporating photosensors can take advantage of this property and can be designed so that inputs can be "read" by photosensors and this information can be relayed.

Prepared in the Engineering Casewriting Course at Stanford University by Mitchell Blanton under the direction of Karl H. Vesper. The cooperation of Mr. Warren Deutsch and the Philco-Ford Corporation in making this material available is gratefully acknowledged.

A Description of Mr. Deutsch's Job

Mr. Deutsch (see attached resume, Exhibit A-1) described his position within Philco-Ford as being "relatively autonomous" inasmuch as value engineering was an activity which cut across other departments. He spent much of his time working on engineering problems he had discovered himself around the plant. The Value Engineering Department didn't evaluate all the equipment that was put out by Philco; instead, when Mr. Deutsch or another member of the department observed something that looked like it might be improved they would endeavor to determine if a better method did indeed exist. "To be successful in my line of work," said Mr. Deutsch, "it is essential that you have a good general knowledge of techniques stemming from a wide background, a natural inquisitiveness, and a good imagination." Excerpts from the Value Engineering checklist of another company appear in Exhibit A-2. An excerpt from government procurement regulations describing Value Engineering appear in Exhibit A-3.

In response to the question of whether or not he followed procedures as outlined in Value Engineering books[2] Mr. Deutsch said, "I don't work from checklists or a regimented procedure, but rather start at one point and proceed by a process of association. For example, there's the well-known problem of machine failure due to the breakdown of components because of excessive heat. In testing equipment then, it would be nice if there were an easy way to detect this excessive heat in particular components. I was reading Life magazine the other day and I came across an article on paints which diffuse into materials and change color with different degrees of temperature. I associated this characteristic of the paint with the problem mentioned above and am presently investigating the possibility of using the paint to detect which machine parts will fail because of heat. In working through association like this I can end up anywhere but have found that there's no such thing as a 'blind alley'. Any end result that is rejected yields clues which are indications of doing things another way. These clues provide a starting point."

[2] For a description of these procedures, see Miles, Lawrence D., Techniques of Value Analysis and Engineering, McGraw-Hill, New York, 1961, p.267.

"Any problem invariably gets bogged down some time or other; I may reach a point where I can't think of solutions or I may simply get tired of working on it. There's also a lot of delay involved in clearing up 'red tape' in the mechanics of obtaining needed materials and in testing the efficiency and customer appeal of a product. For example, as a hobby at home I'm designing a better potter's wheel. I've sent a number of prototypes to schools in the area where they're being tested. I'll use the feedback from these tests to work out any bugs that develop, but until this information comes back, which might take weeks, I'm stymied. So I've found that I produce best when I have three or four problems going at the same time -- when one gets waylaid I can take up another."

"A book will tell you that a value engineer is supposed to come up with 1) a better product at the same cost, 2) an equally useable product at a lower cost, or 3) a more efficient product at perhaps a slightly higher cost. I suppose if you took a distant view of my work you would find that I satisfy these requirements. But I'm rarely conscious of them. I consider my job to be problem solving."

Satellite Control

Man-made satellites are intended to orbit the Earth and send back information useful to scientists. A limiting factor is their lack of power for sending information continuously. Consequently, provisions are made for sending it intermittently, and ground control stations are thus equipped with instrumentation for sending commands to a satellite controlling its functions. For example, to learn the temperature of the satellite the operator at the control station can push a particular button, pull a switch, or turn a dial to "tell" the satellite to send back a reading. With a similar manipulation the operator can open the satellite's solar vanes. For the typical satellite there are about one hundred such functions which might be controlled at the ground station by an instrument such as the one with which Mr. Deutsch had become involved.

Philco-Ford manufactures satellite control equipment. The Human Factors Department at the plant in Palo Alto was testing the instrument panel which Mr. Chavonec had shown to Mr. Deutsch. One wall of the testing room was one-way glass on the other side of which was the testing equipment. The Human Factors Team at Philco would simulate actual satellite control situations on the panel and observe from behind the glass how the operator reacted. Thus they tried to determine the ease and effectiveness with which he manipulated the controls on the instrument panel. Illustrations of typical control rooms appear in Exhibit A-4, which shows a "tracking console" similar to that on which the panel of interest to Mr. Deutsch was to be mounted.

The Operation of the Existing Panel

The part of the instrument panel being tested with which Mr. Deutsch was concerned was called the Page Overlay Keyboard (POK). It was the man-machine interface in a system for satellite control (like the "tracking console" in Exhibit A-4), and was part of a large console. It had been designed at the Philco-Ford plant in Houston, Texas.

From the operator's point of view the POK panel (Exhibit A-5) consisted primarily of 32 buttons. Pushing any one of the buttons would make the satellite perform a particular function. Since the panel was to be used for a wide variety of satellites, whose functions differed greatly, provisions had to be made whereby the panel could be adapted to each satellite. The Philco engineers in Houston had dealt with this problem by devising an overlay system. "Books (Exhibit A-6) containing 10 "pages" with holes corresponding directly to positions of buttons of the panel had been constructed. Each satellite would have a particular book associated with it. For a given satellite a book was to be selected by the operator and inserted in the slot in the instrument panel. Photosensing devices in the slot would tell the machine which book was in place (therefore, which satellite was in operation). A particular page of the book would be selected, placed over the buttons and held down by a bar (Exhibit A-7) which also contained photosensing devices which told the machine what page was in place. The function associated with each button was determined for the machine by which book and page were in place.

Deutsch's Reaction to the POK

"When John explained the operation of the POK", said Mr. Deutsch, "I immediately thought I saw opportunities for improvement in both its mechanical and human factors. I stood beside the console and flipped through the motions needed to operate a satellite. In particular, I had uneasy feelings about the pages being contained in a book and about the fact that the photosensor bar had to be lifted and replaced every time a page was turned. I checked the customer specification and found that the POK as designed fulfilled the stated requirements."

"One of the first things that occurred to me was that the book system provided for 320 functions (32 per page, 10 pages per book). My experience with satellite programs gave me the intuitive feeling that this number was too high. I made a few calls around the plant and got some copies of satellite programs that Philco had recently been involved with. From these it appeared that no one satellite would ever be required to perform more than 100 functions, and that all satellites had about 60 functions in common. These values, though far from accurate, seemed to me in the right ballpark and I felt they substantiated my belief that the book system provided for more future growth than I thought was necessary. "That afternoon I came up with the idea of having the pages contained in a well-like structure (Exhibit A-8). The operator had merely to select a page from the well and place it over the buttons. That way the book system was eliminated. However there still seemed to me to be quite a lot of wasted time and motion and I was sure that there were other possibilities to explore. I decided that I would find out all I could about the POK."

"The Human Factors Department had been working with the POK, and a good friend of mine, Stu Langdoc, was on that team. I had a hunch he might be able to give me some information. As it turned out he had become interested in the POK as a result of attending a briefing at ASCO earlier in the year at which it was discussed. He learned that once the satellite was in operation the pages on the keyboard could not be turned. It thus

seemed to him that the rest of the pages in the book were superfluous. This led him to the idea of having only a single page overlay. Stu explained that in satellite control the operator uses the panel relatively infrequently and therefore he felt that the major design criterion to be met was simplicity of operation, and what could be simpler than a single page? Stu had carried out a preliminary study to determine exactly how many functions were required of a satellite. He found that there were 11 functions common to all satellite programs and about 40 that were variable. He thus felt, and I concurred, that the size of a single page overlay could be one that allowed for 51 functions. But in deference to future growth a switch matrix of 17 x 8 was agreed upon. Stu's information and ideas intrigues me and I decided to investigate the 'hows' of a single page system. There was no doubt in my mind that with a reduction of 214 computer controlled functions there would be accompanying cost reductions in programming and manufacturing.

RESUME

Warren A. Deutsch
823 Rorke Way
Palo Alto, Calif. 94303

Married, 4 children Age: 40 5'8" 180 lbs.

Education: Bronx High School of Science, 1947

University of Chicago, Physics, 1951-1953

Work Experience:

1963-Present

Philco-Ford Corporation, Western Development Laboratories, Palo Alto, California

Value Engineering and Advanced Techniques Manager, Aerospace Ground Operations

As Value Engineering Manager, responsibilities include the initiation and evaluation of Value Engineering ideas, selecting engineers/specialists for fact finding teams, control of funding for investigations, consulting services, and materials appropriate to the area of interest, preparation and presentation of final Value Engineering Proposals to management and the customer (USAF, NASA, etc.). Directly responsible for the development of a floundering program into a profit center which last year earned fees equivalent to 1.5 million dollars in new business.

Recipient of an award presented by the Air Force in recognition of outstanding contributions to their Cost Reduction Program.

The Advanced Techniques office acts as the focal point for the collection and dissemination of various types of information that for the most part represents ideas and techniques developed by both private and government-sponsored programs. Categories of information collected include medical, mechanical, electrical, electronic, chemical and computer programs. The proper dissemination of this information requires a wide range of knowledge and interest as well as a constant awareness of divisional, program and individual needs and interest. In addition, it requires the ability to adapt information derived of one discipline to the requirements of another.

Engineering Specialist, Product Assurance, Reliability Department

Staff to the Manager. Responsible for special programs and projects including use of computer collection and processing of reliability data in conjunction with a program designed to integrate purchasing, vendor, quality, material, where used and use data; use of infrared microscope as a quality control tool, as a reliability test monitoring instrument, and operational fault-finding monitor.

Provided technical assistance to other departments and participated in inter-departmental study teams as a representative of the Reliability Department.

1963

Israel Aircraft Industries, Lod, Israel

Consultant to the Associate Director

Developed an organizational plan that reflected the functional relationships of the electronic division's various activities and anticipated a rate of growth approximating 100 percent per year for several years. Advisor to the departments of Engineering, Manufacturing, Quality Control and Material on questions of function and procedures.

Demonstrated that unused materials after some modification could take the place of scarce, expensive or unobtainable materials. For example, fiberglass insulation and burlap became modular ceiling tile for acoustical treatment in noisy areas. Aircraft scrap was fashioned into playground equipment as the company's contribution to the communicty.

1959-1963

Philco Corporation, Western Development Laboratories, Palo Alto, Calif.

Manager, Failure Analysis Laboratory

Proposed the establishment of a Physics of Failure Laboratory as a natural adjunct to Reliability's function and necessary for a better understanding and control of the physical factors affecting Reliability. Developed complete plan for its budget, layout, instrumentation and personnel. Assigned the responsibility for carrying out the plan; construction, installation of instrumentation, and selection of personnel. In addition became a registered industrial radiologist and health physicist. Performed tests necessary to receive State approval of facility and military approval of procedures. Appointed Manager responsible for (1) analysis of all part failures which occur in the development, fabrication, test shipment and operation of Philco WDL satellite-systems equipment, and (2) developing a test and analysis program for determing the mathematical relationships between environments and failure-causing changes in part materials - the ultimate goal is reliability prediction based on the calculation of part behavior in a given environment rather than the projection of empirical data. Specializing in the analysis of semiconductor failures and the development of advanced failure-analysis techniques.

Designed and built a transistor case cutter that in no way introduced contaminates into or injured the devices. Systems then used by industry injured the device or were time consuming and in some instances used acids. The cutter could be used by a technician and usually did not take longer than three minutes to complete the operation.

Was instrumental in discovering a fault in the manufacturing techniques used in producing a monolithic glass semiconductor diode. Defect, discovered by the use of x-ray, would have caused a number of satellite equipment failures.

Examination of hydraulic fluid from failing servo-valves disclosed the source of contamination as coming from another system component. This work lead directly to a redesigned part and a procedure that provided a check on the condition of the entire system.

Engineering and Administrative Assistant to Manager
Reliability Assurance Department

Liaison between Reliability Assurance Department and engineering laboratories to assure effective integration of reliability and engineering efforts. Responsible for the direction of engineering efforts within the Reliability Assurance Department; recommendation and implementation of procedural and organizational changes to increase the effectiveness of the reliability program.

Senior Engineer, Reliability Assurance Department

Initiated study of high-altitude environments similar to previous investigation for Admiral Corporation.

1959

Lockheed Aircraft Company, Missiles and Space Division,
Sunnyvale, California

Senior Instrumentation Engineer

Reviewed procurement requirements for major items of environmental equipment; prepared procurement specifications. Performed technical evaluation of manufacturers' bids and liaison between manufacturers and engineering departments. In many cases made major modifications to engineering designs and introduced a method by which purchasing could evaluate bidders.

1959

Armour Research Foundation, Chicago, Illinois

Research Associate

Evaluated nondestructive vibration testing of miniature and sub-miniature electronic tubes as a method for predicting tube reliability. Determined that the operational behavior of commercial test equipment varied sufficiently to prevent correlation of results obtained from different test facilities. Test program amended to establish Armour as the sole test facility.

1958-1959

ECM Laboratory, Admiral Corporation, Chicago, Illinois

Senior Engineer, Physicist

Surveyed existing reliability test and evaluation facilities; recommended improved use of existing facilities and new facilities necessary for establishing a more effective reliability-evaluation program.

Reliability Evaluation Laboratory Director

Appointed Laboratory Director responsible for establishing new Evaluation Laboratory in accordance with recommendations resulting from facilities study.

Studied high-latitude environments for the purpose of defining environmental conditions more precisely and reducing, if possible, the 'environmental support' equipment required for high-performance aircraft systems.

Results of this study were used: (1) as a basis for writing specifications for equipment in the research and development stage, and (2) to establish realistic environmental test requirements for reliability evaluation.

1954-1958

Hallicrafters Corporation, Chicago, Illinois

Director, Reliability Laboratory

Responsible for planning and supervision of reliability testing; program included test of Atlas Missile System fuel and hydraulic-system components and a variety of ECM equipment in the IF, IR, and visible spectrums.

Engineering and Administrative Assistant to Reliability Laboratory Director.

Responsible for the analysis and evaluation of reliability test data and the preparation of evaluation reports. Prepared costing and technical information for proposals issued in response to request for reliability testing received from other firms.

Engineer

Designed miniaturized circuits for Electronic Counter Measures equipment. Circuits developed included a sweep generator, IF amplifier, and audio amplifier which were considerably smaller than contemporary circuits of comparable electrical characteristics and reliability.

1953-1954

Institute for the Study of Metals, University of Chicago

Research Technician

Studied the crystalline structure of various Boron steels. Participated in an extended study of Alpha and Beta brasses to determine the cause and structural significance of a metal-temperature 'plateau' which occurs when these materials are exposed to a gradual temperature increase. Performed micro-hardness tests and x-ray analysis of test specimens and statistically reduced data obtained. Designed a photographic specimen-jig for positioning specimens during x-ray analysis.

Partial Value Engineering Checklist

(Developed by another company for use by its Design Review Committee)

1. Have the customer's specifications been subjected to a systematic review to determine whether they require more than is needed? Do they include excessive cost-producing requirements relative to high temperature, shock, vibration, or other environments?

2. Have engineers challenged the design of individual components with respect to economy and suitability of manufacture? For example, shall a part be machined, cast, forged, or welded?

3. Have quantities of parts required for the development program and their costs been considered?

4. Have designs been challenged with the objective of recommending better designs when they represent lower cost while retaining the required functions?

   a. What is the function of a given part? Is it required?
   b. How much does the present design cost?
   c. What else will perform the same function? At what cost?

5. Have standard off-the-shelf items been used in the design wherever reliable items are available? Have potential vendors been consulted for alternatives or modifications that would reduce costs?

6. Does the design represent optimum simplicity commensurate with functional requirements? Can any part be eliminated or combined with another part to reduce the total number of parts and cost?

7. Has relative workability and machinability of materials been considered? Have specifications been reviewed to eliminate unnecessary requirements? Can the design be modified to use the same tooling for right and left handed or similar parts? Are all hand operations essential? Could furnace brazing be substituted for manual welding, for instance? Do hole sizes use standard drills? Has deep hole drilling been minimized?

8. Have experienced engineering and manufacturing specialists been consulted where they can likely help with the design? Have tool and manufacturing engineers reviewed the design before release of prints?

9. Are all machined surfaces necessary? Could less expensive finishing be used? Has the required finish been specified at the proper stage of completion to minimize damage during subsequent handling?

10. Are all parts designed for assembly at the earliest possible time considering that assembly costs increase as system build-up progresses? Have state-of-the-art bonding techniques been considered for applications requiring riveting, bolting, and their associated finishing operations?

Exhibit A-3 **- Excerpt from Armed Service Procurement Regulations**

Part 17—Value Engineering

1-1701 Policy.

(a) *General.* Value engineering is concerned with elimination or modification of anything that contributes to the cost of an item but is not necessary to required performance, quality, maintainability reliability, standardization, or interchangeability. Value engineering usually involves an organized effort directed at analyzing the function of an item with the purpose of achieving the required function at the lowest overall cost. As used in this Part, "value engineering" means a cost reduction effort not required by any other provision of the contract. It is the policy of the Department of Defense to incorporate provisions which encourage or require value engineering in all contracts of sufficient size and duration to offer reasonable likelihood for cost reduction. Normally, however, this likelihood will not be present in contracts for construction, research, or exploratory development. Value engineering contract provisions are of two kinds:

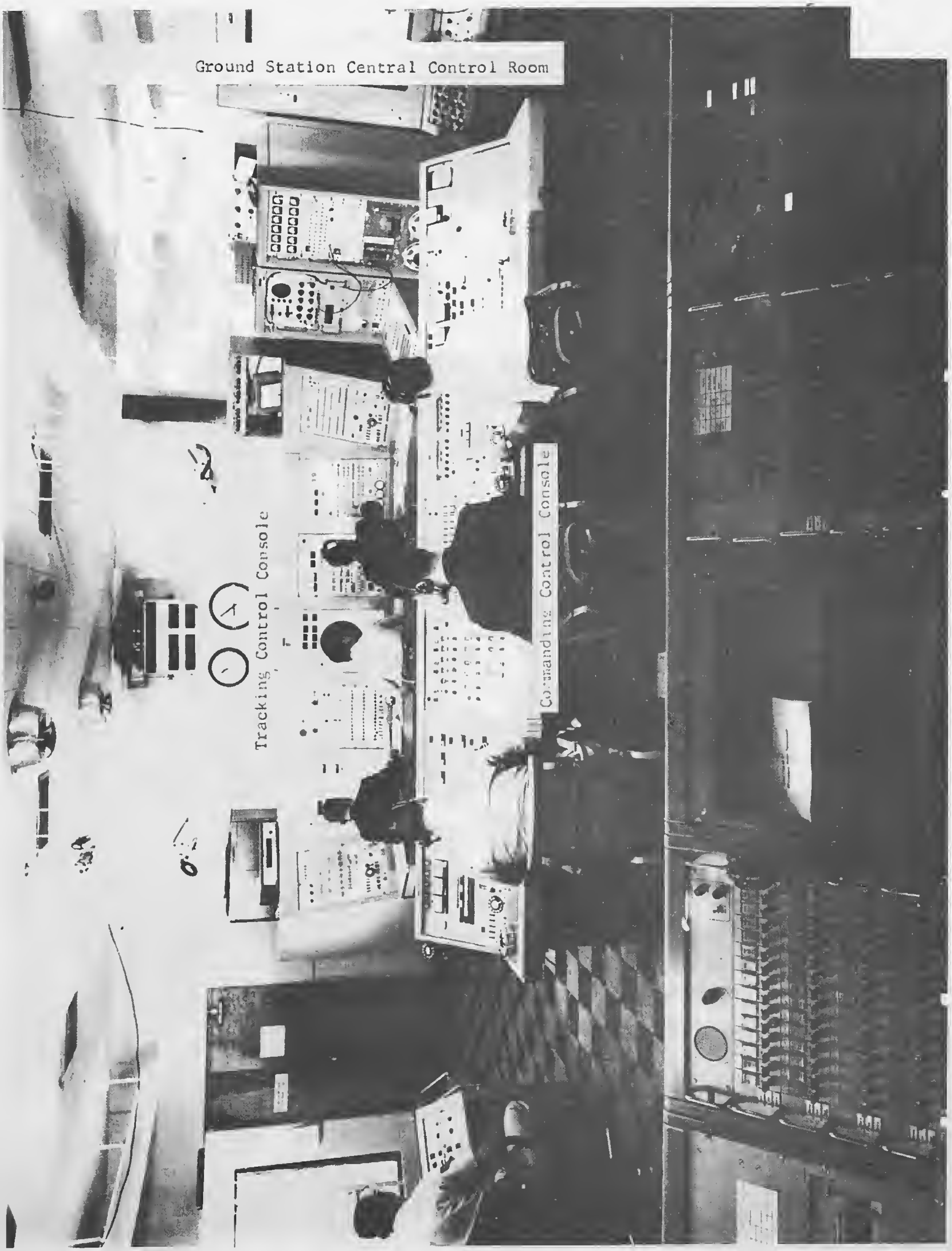
(i) value engineering incentives which provide for the contractor to share in cost reductions that ensue from change proposals he submits; and

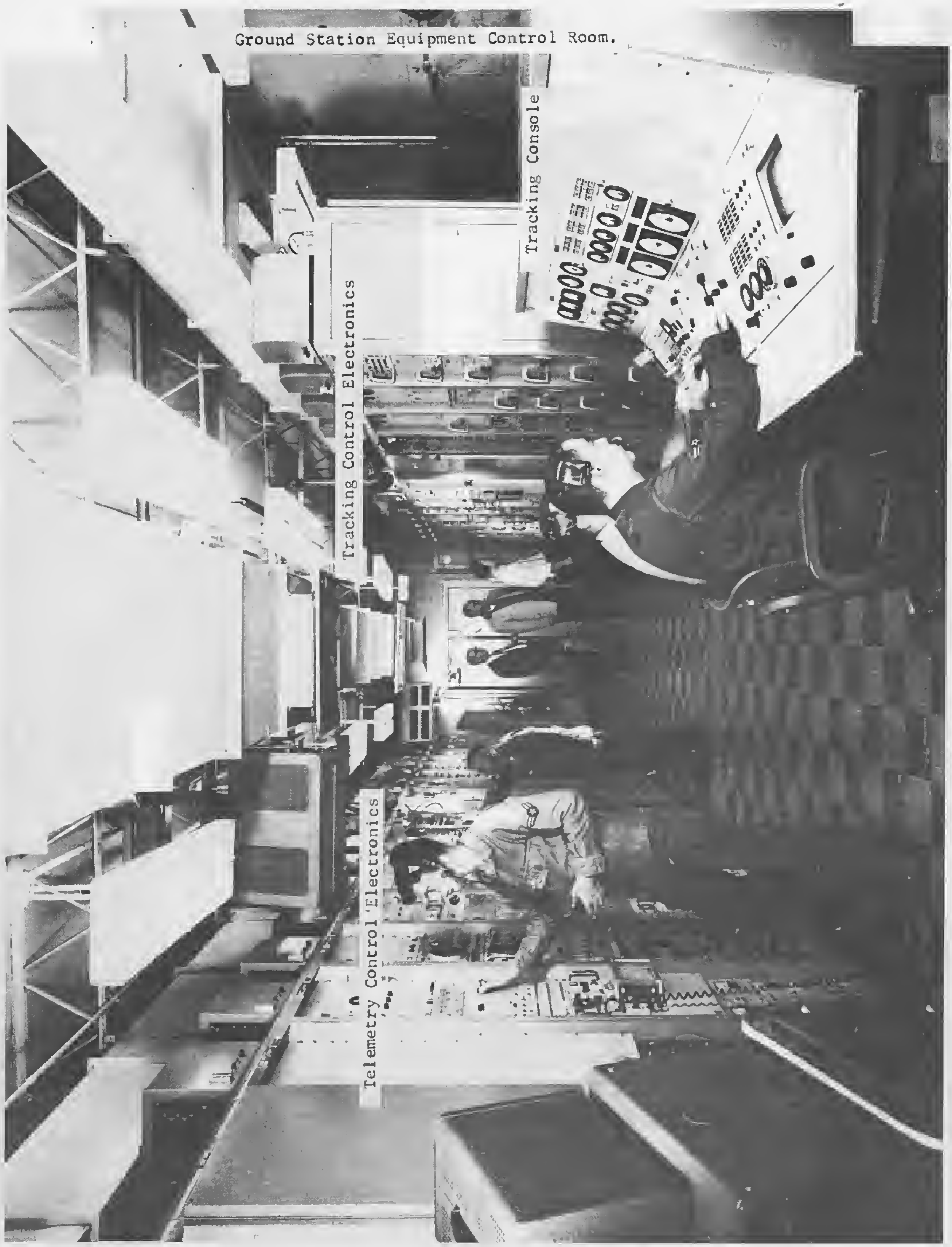
(ii) value engineering program requirements which obligate the contractor to maintain value engineering efforts in accordance with an agreed program, and provide for limited contractor sharing in cost reductions ensuing from change proposals he submits.

(b) *Processing Value Engineering Change Proposals.* In order to realize the cost reduction potential of value engineering, it is imperative that value engineering change proposals be processed as expeditiously as possible.

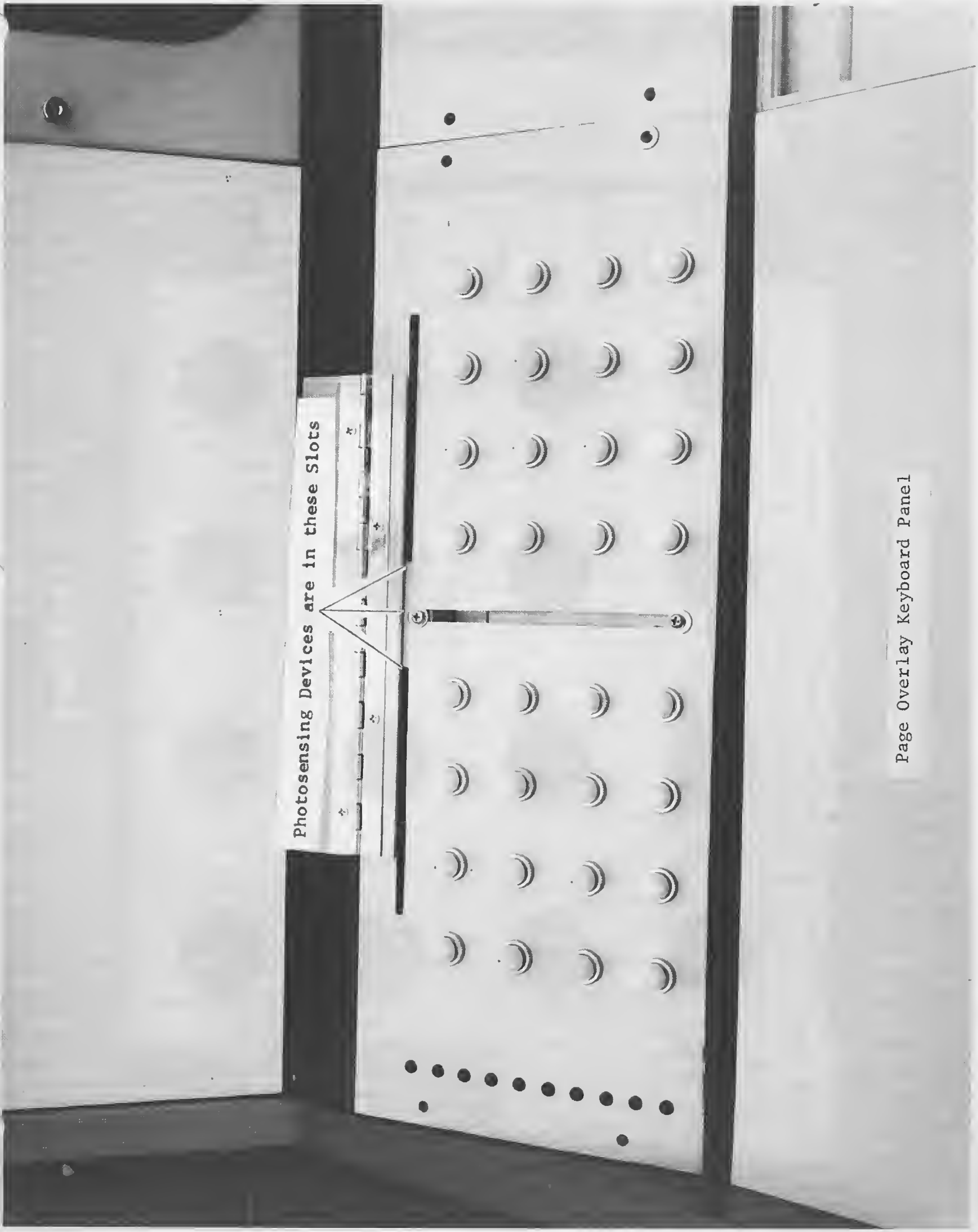
1-1702 Value Engineering Incentives.

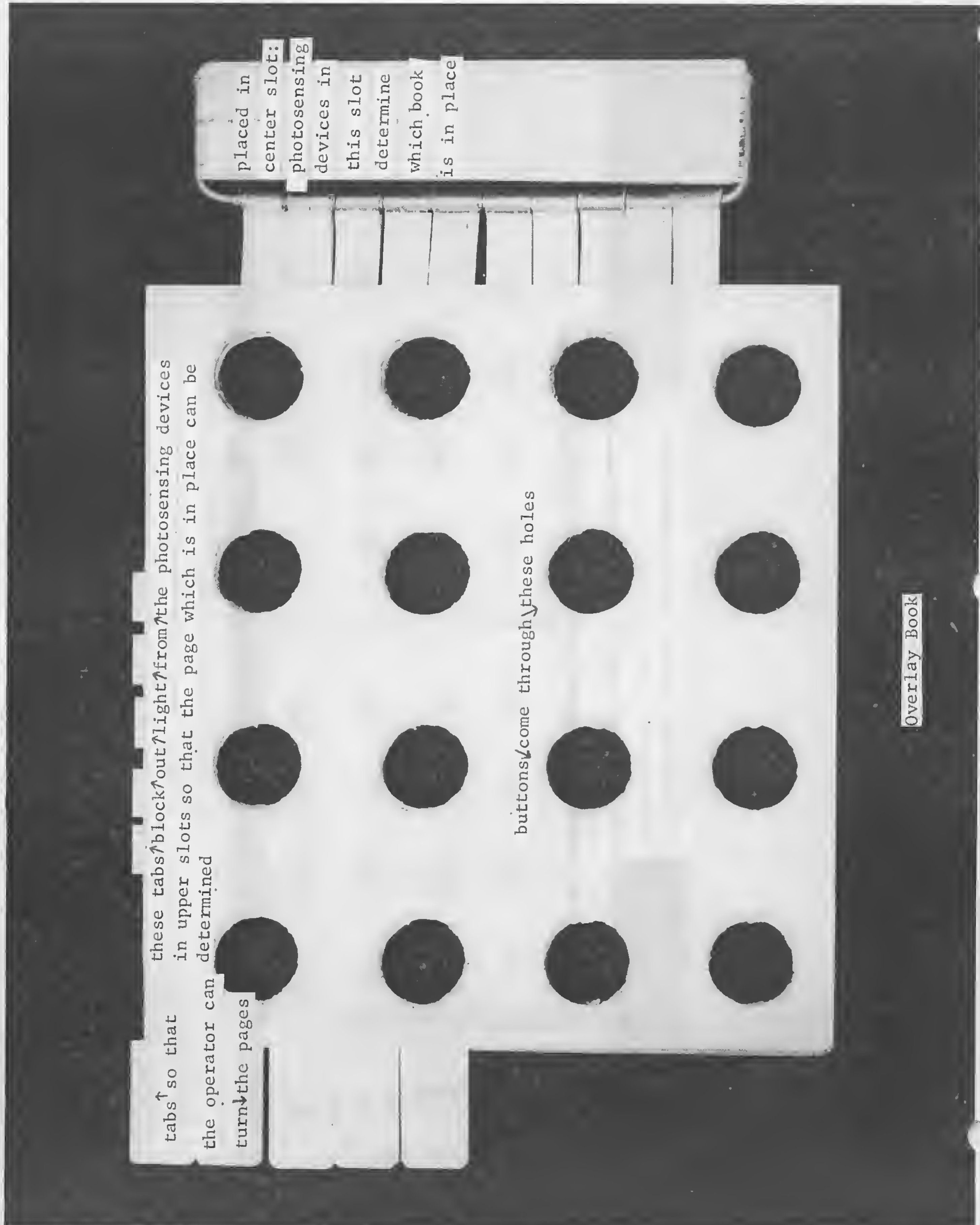
1-1702.1 *Description.* Many types of contracts, when properly used, provide the contractor with an incentive to control and reduce costs while performing in accordance with specifications and other contract requirements. However, the practice of reducing the contract price (or fee, in the case of cost-reimbursement type contract) under the "Changes" clause tends to discourage contractors from submitting cost reduction proposals requiring a change to the specifications or other contract requirements even though such proposals could be beneficial to the Government. Therefore, the objective of a value engineering incentive provision is to encourage the contractor to develop and submit to the Government cost reduction proposals which involve changes in the contract specifications, purchase description, or statement of work. Such changes may include the elimination or modification of any requirements found to be in excess of actual needs regarding for, example, design, components, materials, material processes, tolerances, packaging requirements, or testing procedures and requirements. If the Government accepts a cost reduction proposal through issuance of a change order, the value engineering incentive provision provides for the Government and the contractor to share the resulting cost reduction in the proportion stipulated in the value engineering incentive provision.

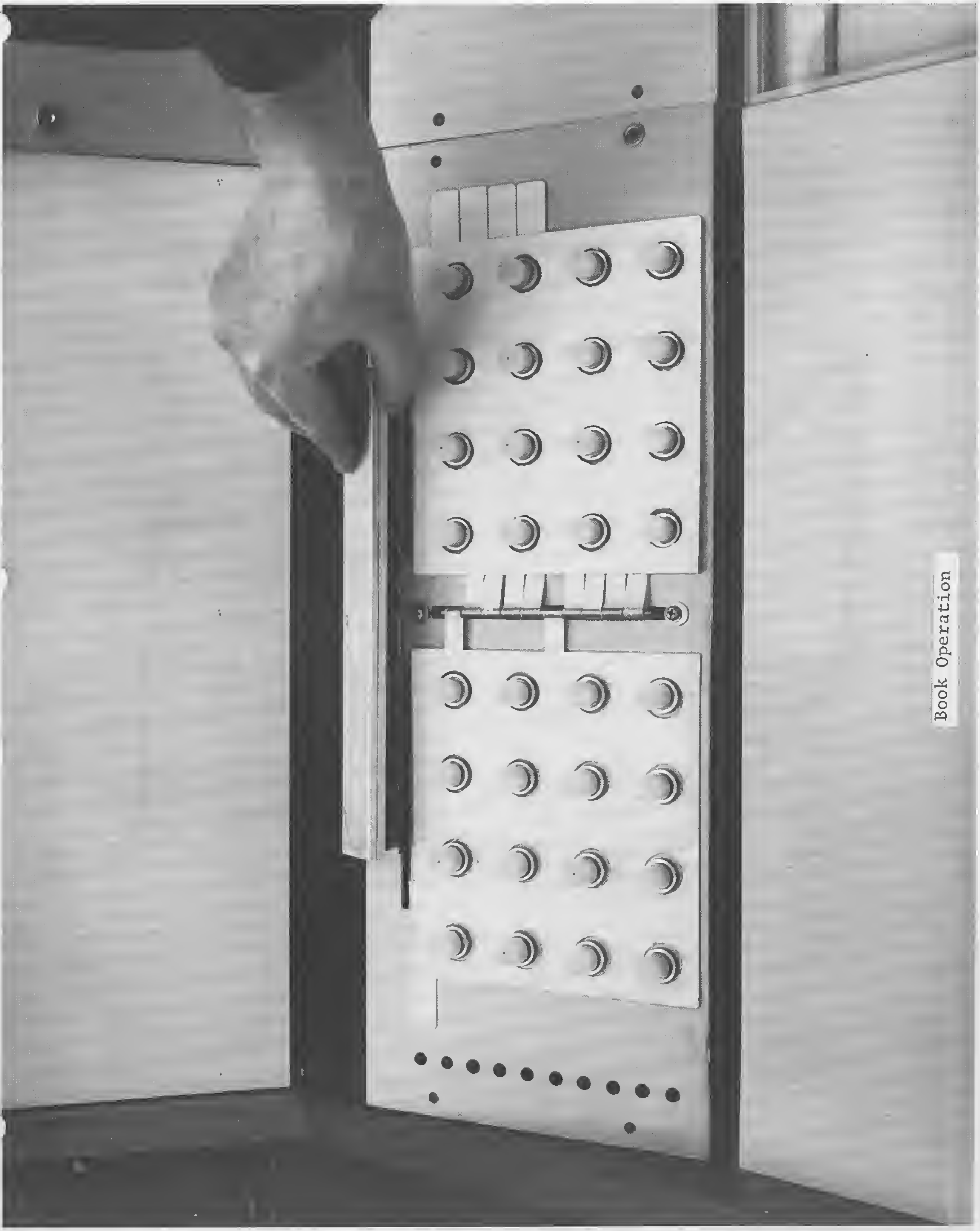

Ground Station Central Control Room
Tracking Control Console
Commanding Control Console



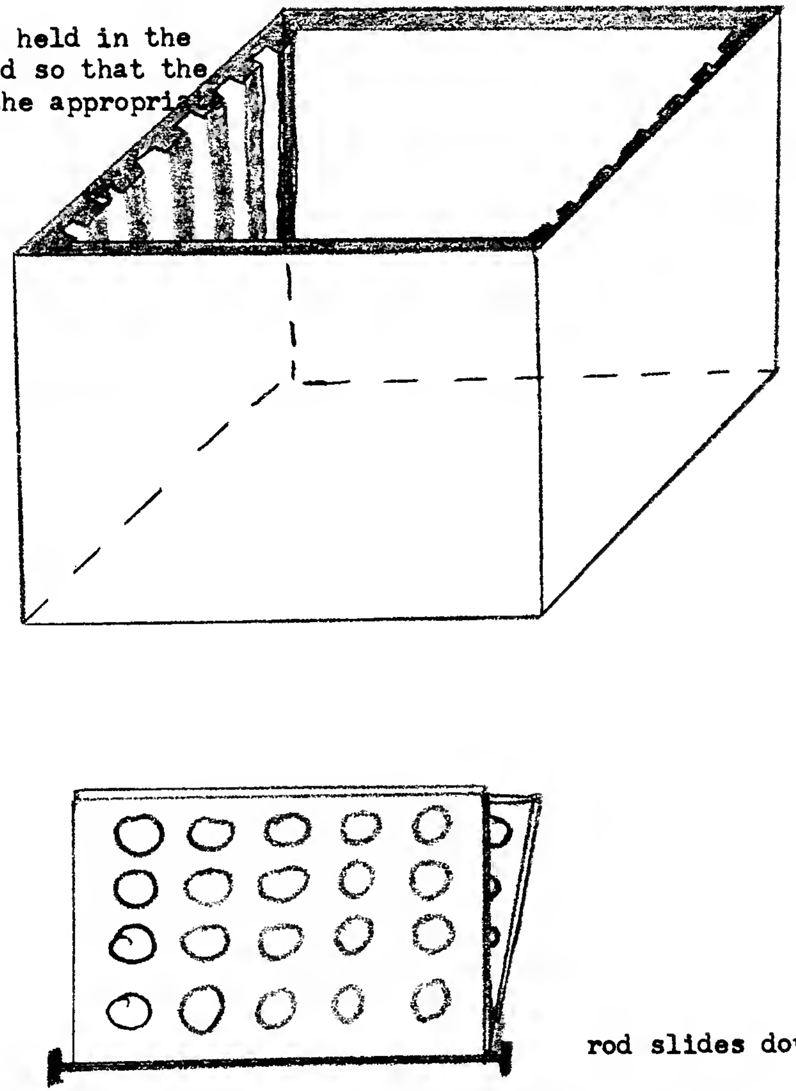
Ground Station Equipment Control Room.


Photosensing Devices are in these Slots
Page Overlay Keyboard Panel


placed in
center slot:
photosensing
devices in
this slot
determine
which book
is in place
these tabs block out light from the photosensing devices
in upper slots so that the page which is in place can be
determined
tabs so that
the operator can
turn the pages
buttons come through these holes
Overlay Book



Book Operation



Mr. Deutsch's W[illegible]l Idea

ECL 124B

ENGINEERING CASE LIBRARY

Warren Deutsch:
Design of a Satellite Controlling Instrument Panel (B)

Mr. Deutsch had settled on a single page overlay system for the controlling panel. He found it helpful in following through the idea to discuss it informally with Stu Langdoc and other members of the Human Factors Department who understood the specifications to be met. "For instance", said Mr. Deutsch, "Stu pointed out that the best method of operation was pushing buttons because the operator would feel more 'at home' with the system. Because of this suggestion, because the POK system had used buttons, and because I was more familiar with buttons, I decided to work with push button type switches on the keyboard."

A number of problems now arose. Nomenclature had to be associated with each button so that the operator could tell what function would be performed by the satellite when he pushed a particular button. In the POK system the nomenclature had been written below each hole in a page so that when the page was in place the nomenclature would appear below each button. But the POK had used only 32 buttons and Mr. Deutsch had deduced that a single page overlay system might require as many as 110 buttons. "I wasn't sure if there was a specific area on the console to which the keyboard would be confined," said Mr. Deutsch, "but I knew that if the keyboard became too large it would make it tougher on the operator. So I ruled out the possibility of putting it below the buttons because this would make the keyboard too big. The answer was fairly obvious to me; somehow put the nomenclature on the overlay covering the buttons. I wasn't sure how I could do this but I stored the idea in my mind with intentions of working out the 'hows' later."

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ing the overlays when they were processed because we thought it would be too expensive. Instead we knew we had to adapt the overlays once we had gotten them from the manufacturer. I thought about it and came up with an idea which would also allow for putting the nomenclature above the buttons as I wanted. The overlay could be designed so that plastic inserts could be placed below each area on the overlay corresponding to a button (Exhibit B-3). The nomenclature would be printed in black on the first insert, which otherwise would be clear and transparent. A translucent solid colored insert would go below this. The vinyl overlay would be clear and transparent. The operator would see through the overlay and the black nomenclature would appear superimposed on a solid color.

"I was happy with this idea but Stu pointed out that at any one time there would be functional areas which would be inactive temporarily. He felt it would be nice if these (i.e.,their colors) could be temporarily obscured and appear as white to the operator. For example, a typical satellite program might have a sensing device -- call it the XYZ -- contained within the satellite that, when exposed to the atmosphere, obtained several bits of information and sent them back to the control station. Two different functional areas are represented here. A red (arbitrarily selected) area would control mechanisms of the satellite and thus contain a button which would operate a mechanism that would expose the XYZ to the atmosphere as well as another to bring it back into the satellite again. The other functional area, a green one, would control sending the information from the XYZ and would contain buttons for getting the 1) temperature, 2) pressure, and 3) the percent oxygen in the air from the XYZ. When the XYZ is inside the satellite it is incapable of obtaining information and thus the green functional area would be inactive. Because of this we would want the green area to appear temporarily as white. But when the button in the red area is pushed which exposes the XYZ to the atmosphere the green area becomes active and the operator should see it as green rather than white.

"I thought this over for a while and finally came up with a scheme which would meet Stu's demand. The vinyl overlay could be translucent white rather than clear. Each button would have a light in it controlled by the computer. When the light was on the color and nomenclature would

show through the overlay -- when the light was off the button would look white. Say initially the XYZ is in the satellite. The lights in the red area would be on while those in the green area would be off. The red functional area would be lit red but the green functional area would be temporarily white. Suppose then that information is needed from the XYZ. The operator looks into the red area for the appropriate button, pushes the one exposing the XYZ to the atmosphere. When he does this the computer turns on the lights in the green area, the green color shows up in place of the white, and the operator can now read the nomenclature of the buttons in the area."

Just as with the POK system the computer had to be able to "read" which overlay was in use. "There was an obvious way to do this," said Mr. Deutsch, "stemming from the POK system. Each overlay would be coded, and sensing devices on the panel would read this coding. I decided that this coding could go on the edges of the overlay while the sensing devices could be positioned appropriately on the panel (see Exhibit B-4). This idea seemed very reasonable and I decided to stay with it. I immediately rejected the use of photocells for the sensing devices. They're double active devices, meaning that the light in the cell could burn out or the light receiver would go on the blink. In either case the system would fail to read the overlay properly. Another thing which led me to reject photocells was that amplifiers were needed to raise the current from the photocell. Several other sensing devices came to mind -- the microswitch and the magnetic reed switch.* I'd seen these types of switches in other projects I'd worked on and was fairly familiar with them. I didn't know if either would be practical for our design, so I took the magnetic reed switch, built a small mock-up, and tested it. It worked fine. The reed switches could be imbedded in the console with a magnet next to each biasing it to the inactive position.

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*magnetic reed switch (Exhibit B-5) has a reed which can be magnetically biased to an open or closed position (that is, either short circuited or open circuited). When another piece of iron comes near, it shunts the magnet to the different bias (i.e., if open originally it becomes closed when iron is brought near). A microswitch is one which is activated by physical application of very light pressure.

Each overlay would have pieces of iron foil imbedded strategically in its edges. When the overlay was put in place, the switches which happened to be under the iron foil would have their magnetic field shunted and the reeds would switch to their closed positions. Thus by designing the placement of the switches and foil properly and then programming this information into the computer, the computer could "read" which overlay was in place. As an added benefit I found that the magnet had sufficient strength to hold the overlay in place."

Another specification that occurred to Mr. Deutsch was providing for the prevention of pushing more than one button at a time. The buttons were to be located very close to each other so it was possible that the operator could accidentally push more than one button at once. "In the past I've often come across the use of interlock systems," said Mr. Deutsch, "they are commonly used in devices like typewriters where only one of many adjacent buttons is to be pushed at any one time. But I knew that this interlock method was fairly complex. A lot of hardware is needed and it is expensive. I decided that I'd try and think of a better method. I thought about the problem and after a while came up with the idea of putting a barrier around each button. If you were pushing a particular button and your finger slipped it would hit the barrier and not another button. In exploring this idea further I thought of the old-fashioned eggcrates. These were made up of wood slats arranged in honeycomb tiers and I thought that a similarly constructed tier, when placed around the buttons on the keyboard, would prevent pushing more than one button at a time, just as the tiers in an eggcrate keep eggs from hitting each other and breaking. I reviewed available literature and found that several companies had developed this barricade idea and had models for sale. I followed up these leads, got literature from the companies, and reviewed the specifications of each to see which of the barriers would be most adaptable to the panel. Several seemed suitable so I selected one and examined it carefully. It was constructed of "slats" (depicted in Exhibit B-6) which were held together by long hollow rivets. In order to place the matrix (i.e., the company which made it called the barrier configuration a "matrix") in a console, a frame was built onto the perimeter of the matrix and this in turn could be screwed to the console. It seemed to me that this frame might present complications in that when the overlay was placed over the matrix, the frame would cause it

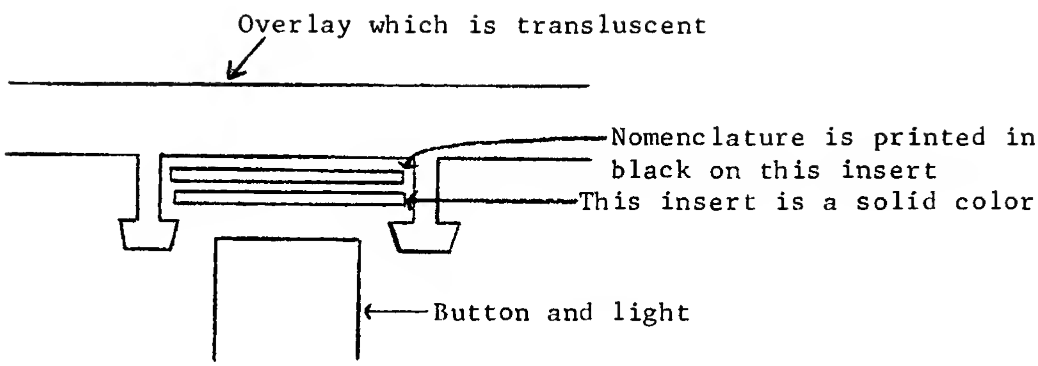
to be slightly raised from the console and this would make it difficult to provide for a proper connection between the iron foil on the overlay and the reed switch in the console. I tried to think of a way to modify the matrix so that the overlay could hit flush with the console. My first thought was to somehow get rid of the frame, as it was causing the problem. It would be easy to do without the frame but in doing so I had to create another provision for securing the matrix to the console. I thought about it for awhile and got a brainstorm -- the hollow rivets tipped me off. Thin metal rods could run through the rivets and bracket to the console's wall below the surface. This would secure the matrix and allow for a flush interface between the matrix and the console surface."

Mr. Deutsch presented this idea to the company which manufactured the matrix and asked if they would modify it in the above manner. The matrix company reviewed Mr. Deutsch's idea; decided to modify it for him, and also decided to offer it as a design for future customers. Mr. Deutsch pointed out that at this stage the investigation was nowhere near complete and that there would be a continuing evolution of the design based on factors not yet fully evaluated such as cost, ease of manufacture, reliability and ease of operation.

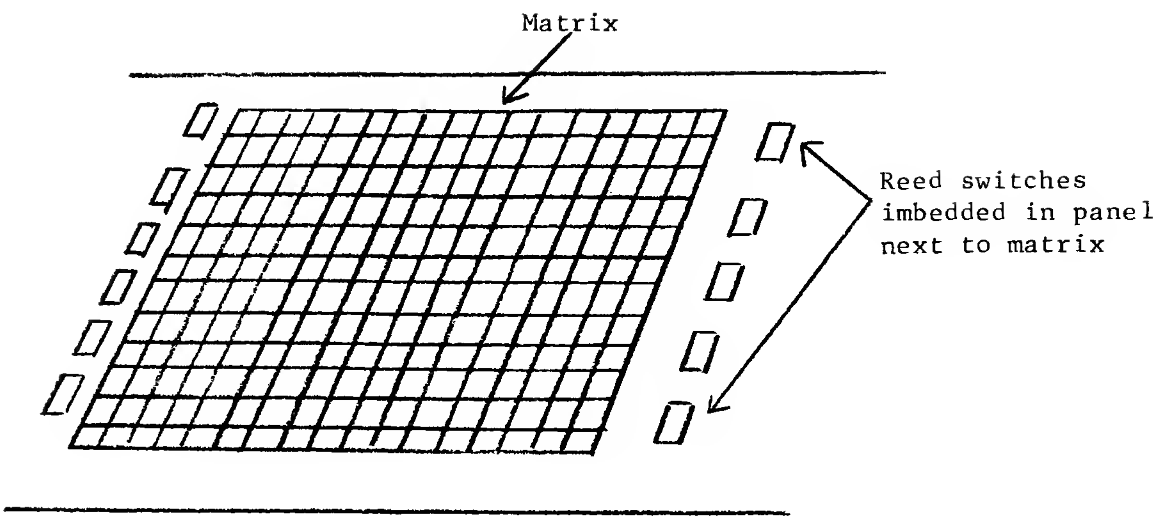
The Program Manager of the project involving the POK added that, although the new idea might be useful on future projects, it was expected that the POK would still be used on this one. He added also that planning information which Mr. Deutsch had not been earlier aware of supported retention of a large number of control functions (button alternatives) to allow for future growth of the system.

Functional Area Cutout Overlay

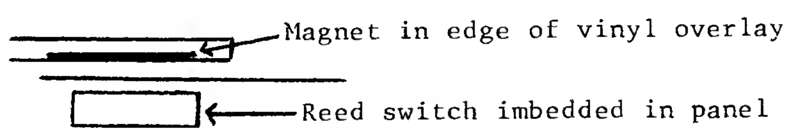

Keyboard



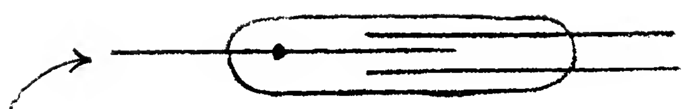
Side view of vinyl overlay and
plastic inserts below



Top View

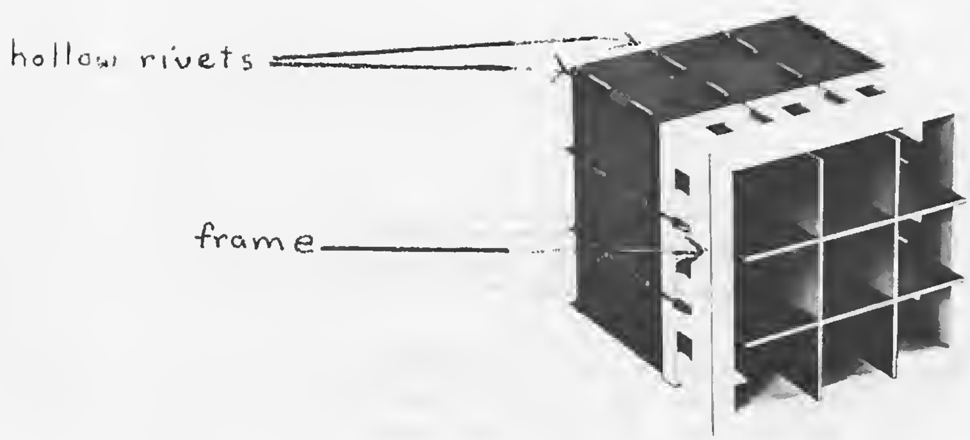


Side View



This piece can be shunted so that it contacts one or the other of the components so that it is either open or closed.

Magnetic Reed Switch



Barricade Arrangement

Mr. Deutsch worked through what he described as a process of association to come up with his next idea. In the POK system with the nomenclature below the buttons there could be holes in the overlay and the buttons could be pushed directly. "But if the new single page keyboard was to be made up of buttons to be pushed," said Mr. Deutsch, "and if the overlay was to have nomenclature covering the buttons, then the overlay had to be flexible so you could push 'through' it to activate the button. I decided to try using an elastic membrane to cover the buttons. I talked to a number of vendors to see what they had and decided vinyl would be the most functional because the other types were too expensive or couldn't take printing."

The keyboard that Mr. Deutsch had decided on was to have roughly 110 buttons. However for a given satellite program the number of functional buttons is likely to be much smaller. For example, if 50 operations were required of a satellite there would be 50 functional buttons and 60 "dead" buttons left over. The 50 functional buttons would normally be separated into functional areas. For example 20 buttons might govern maneuvers of the satellite while the other 30 might pertain to its sending information to the control station. These two groups would represent the two major functional areas. These areas in turn could be separated into minor, smaller, more specific functional areas; i.e.,of the 20 buttons governing maneuvers, 5 might control mechanisms which govern speed, 5 might apply to rotation, and 10 might apply to the orientation of instruments.

With this information in mind, Mr. Deutsch got together with Mr. Langdoc to discuss the design of the vinyl overlay. "We just started talking," said Mr. Deutsch, "remembering that our goal was to make the keyboard simple to operate; and the final design 'fell out'. We decided that the easiest way to do this would be to make a cut-out to accompany each vinyl overlay. This cut-out would be placed over the overlay and only those buttons in the cut-out region would be exposed. The cut-out regions would correspond to the functional areas (Exhibit B-1). Another thing that we decided was that we wanted color coding of the functional areas. That is, if 5 buttons operated mechanisms controlling motion of the solar vanes, we wanted these buttons to be all one color -- say blue. Each minor functional area would be colored differently (keyboard appears in Exhibit B-2). In deciding how to do this we immediately ruled out color-